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USAAEFA PROJECT NO. 79-08

AH-1S(PROD) AIRWORTHINESS AND FLIGHT CHARACTERISTICS FOR INSTRUMENT FLIGHT

FINAL REPORT

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UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The United States Army Aviation Engineering Flight Activity conducted an Airworthiness and Instrument Flight Characteristics evaluation of a Production AH-1S (Prod) to determine potential for the AH-1S with Enhanced Cobra Armament System (ECAS) to meet instrument meteorological conditions qualification criteria. The test aircraft was configured with two tube launched, optically tracked, wireguided (TOW) missile launchers on each outboard wing stores station and a 7-tube lightweight launcher on each inboard wing stores station. The test consisted of 16.3 flight hours which were flown during 12 test flights. Four deficiencies and seven shortcomings associated with flying the AH-1S in instrument flight conditions, were identified. The deficiencies identified were (1) Unsatisfactory cyclic control system mechanical characteristics; (2) Large pitot-static system

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) airspeed errors in climb and descent; (3) Easily excited lateral gust response; (4) Vertigo-inducing location of radio control panels. Five specification noncompliances were noted. The AH-1S (Prod) is not suitable for flight in instrument meteorological conditions, which infers that the AH-1S (ECAS) will also not be suitable.

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SUBJECT: Directorate for Development and Qualification Position on the Final Report of USAAEFA Project No. 79-08, AH-1S (PROD) Airworthiness and Flight Characteristics for Instrument Flight

SEE DISTRIBUTION

1. The purpose of this letter is to establish the Directorate for Development and Qualification position on the subject report. The Airworthiness and Flight Characteristics (A&FC) test was conducted to evaluate the instrument flight characteristics of the AH-1S series helicopters and determine airworthiness qualifications under instrument meteorological conditions (IMC). The original IMC restrictions had been determined based on testing of the AH-1G. Several significant changes had been made to the AH-1S which prompted a new IMC evaluation. These changes included an increased gross weight, SCAS gain changes and airspeed system relocations. Based on the subject report test results the AH-1S cannot be qualified for flight under IMC due to the significant deficiencies identified.

2. This Directorate agrees with the report findings and conclusions. The following comments are made relative to the findings and conclusions and are directed to the report paragraph as indicated.

a. Paragraph 42a. The poor cycle control mechanical system characteristics (longitudinal and lateral) significantly degraded the AH-1S IMC flight characteristics and resulted in an unacceptable pilot workload as well as adversely impacting the pilot's capability of precise aircraft control. Major poor system characteristics included excessive breakout plus friction forces, unbalanced control position gradients and excessively wide trim control displacement bands.

b. Paragraph 42b. The large airspeed position errors exhibited during power changes significantly degraded the pilot's ability to maintain desired airspeeds and rates of climb/descent within reasonable limits under simulated IMC conditions.

c. Paragraph 42c. The easily excited lateral gust response resulted in large roll attitude changes of up to 10 degrees with no tendency for the aircraft to return to the trim roll attitude. This resulted in considerable pilot concentration to correct at the degradation of other cockpit requirements such as navigation, tuning radios and maneuvering during approach.

DRDAV-D
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d. Paragraph 42d. The vertigo-inducing location of the UHF, VOR, ADF and transponder control heads added significantly to the pilot workload under IMC. This deficiency is adversely impacted by the deficiencies discussed in paragraphs 2a, 2b, and 2c above.

e. Paragraphs 43a through 43g. The shortcomings discussed in these paragraphs compounded the difficulty of conducting IMC flight on the AH-1S. When considered in conjunction with the deficiencies addressed in paragraphs 2a through 2d above they resulted in significantly degraded flying qualities under IMC flight.

f. Paragraphs 44a through 44e. The non-compliance to relative paragraphs of MIL-H-8501A or deviations contained in the AH-1S Detail Specification are significant factors in the unacceptable IMC flight qualities of the AH-1S.

3. Correction of the deficiencies specified in the subject report are required for airworthiness qualification of the AH-1S for flight under IMC. Such qualification is feasible with PIP action as stated below.

a. Cyclic control mechanical system characteristics. Short term solutions would require a modified rigging procedure to minimize control function. Long term solution would consist of providing pilot adjustable cyclic friction, changed spring force cartridge and tailoring of spring centering cartridge.

b. Airspeed position error. An acceptable short term solution is not identified. Long term solutions would include possible tie-in to the air data system or relocation of pilot-static system.

c. Lateral gust response. An acceptable short term solution is not identified. Long term solutions would include tailoring roll and yaw SCAS axis gains and lag rate damping for desirable flying qualities.

d. Vertigo-inducing locations of the UHF, VOR, ADF and transponder control heads. Short term solution would be human factors analysis and wiring study to optimize current installation. Long term would consist of human factors analysis and radios study to optimize future installations.

FOR THE COMMANDER:

Charles C. Crawford, Jr.

CHARLES C. CRAWFORD, JR.
Director of Development
and Qualification

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INTRODUCTION

BACKGROUND

1. The AH-1S series helicopter has not been qualified for instrument flight because of inadequate backup electrical power and marginal handling qualities. The installation of a 10-Kilovolt Ampere (KVA) alternator and a transformer rectifier to the electrical system of the AH-1S with the Enhanced Cobra Armament System (ECAS) provides adequate backup electrical power. An Instrument Meteorological Conditions (IMC) evaluation was previously conducted on an AH-1G (Ref 1, App A). Additional flight testing was required on an AH-1S to evaluate the changes in IMC handling qualities caused by the increased gross weight, change in armament configuration, and the installation of a flat plate canopy, as compared to an AH-1G. The United States Army Aviation Engineering Flight Activity (USAAEFA) was directed by the United States Army Aviation Research and Development Command (AVRADCOM) to conduct an airworthiness and flight characteristics (A&FC) test of the AH-1S (Prod) for IMC flight (Ref 2, App A). Previous test of the AH-1S (ECAS) (Ref 3, App A) indicated the stability and control characteristics of the AH-1S (ECAS) and AH-1S (Prod) are essentially unchanged.

TEST OBJECTIVES

2. The test objectives were: a. To quantitatively evaluate the instrument flight characteristics of the AH-1S (Prod) helicopter against the requirements of section 3.6 of military specification MIL-H-8501A (Ref 4, App A), and thereby infer potential for the AH-1S (ECAS) to meet IMC qualification criteria.

b. To qualitatively evaluate the AH-1S instrument flight characteristics during simulated IMC flight.

DESCRIPTION

3. The production AH-1S is a tandem seat, two-place helicopter with a two-bladed main rotor and a two-bladed Model 212 *tractor tail rotor*. The helicopter is powered by a Lycoming T53-L-703 turboshaft engine thermodynamically rated at 1800 shaft horsepower (SHP) at sea-level, standard-day conditions derated by main transmission limitations to 1290 SHP for 30 minutes and 1134 SHP for continuous operation. Distinctive features of the helicopter include the narrow fuselage, stub wings with four stores stations, and a flat-plate canopy. A more complete description of the AH-1S is presented in the operator's manual (Ref 5, App A) and Appendix B.

4. The test aircraft AH-1S (Prod) USA Serial Number 76-22573 was configured with the K747 main rotor blades, two M65 tube-launched, optically tracked, wire-guided (TOW) missile launchers on each outboard store station and an M261 7-tube lightweight launcher (LWL) on each of the two inboard store stations, as shown in Photo A. One flight was performed with four Hellfire missiles installed on each of the outboard store stations, and LWL removed.

TEST SCOPE

5. This A&FC evaluation was conducted at Edwards Air Force Base, California from 2 May 1980 through 8 August 1980. Twelve test flights were flown for a total

of 16.3 flight hours. Flight restrictions contained in the operator's manual (Ref 5, App A) and the airworthiness release (Ref 6) were observed. Flight test conditions are summarized in Table 1.

TEST METHODOLOGY

6. Testing was conducted in two phases. The purpose of the first phase was to quantitatively evaluate the handling qualities characterisitcs using standard test techniques and data reduction procedures described in Reference 7, Appendix A. The purpose of the second phase was to qualitatively evaluate the handling qualities characteristics while performing simulated IMC flight tasks. Performance standards associated with successful performance of the task are those contained in Aircrew Training Manual (Ref 8, App A). During all testing, data were recorded on magnetic tape with pilot comments hand recorded as they were made. The data parameters are presented in Appendix C. For the phase two test, all special test instrumentation and displays were removed from the pilot's station, and the cockpit was configured in accordance with the operator's manual. A Handling Qualities Rating Scale (HQRS) (App D) was used to augment pilot comments relative to handling qualities and instrument flight task.

Table 1. Test Conditions[1]

TEST	FLIGHT CONDITION	AVERAGE GROSS WEIGHT (lb)	AVERAGE DENSITY ALTITUDE (ft)	TRIMMED CALIBRATED AIRSPEED (knots)
Control system characteristics[2]	On[3] ground	NA	NA	NA
Control positions in trimmed forward flight[4]	Climb Level Descent Autorotation	9400	5800	[illegible] 64 44 [illegible] 58 [illegible] 64 48 [illegible]
Static longitudinal stability[4]	Climb Level Descent Autorotation	9200	6800	[illegible] 78 and 105 [illegible]
Static lateral-directional stability[4]	Climb Level Descent Autorotation	9600	6300	[illegible] 104 [illegible]
Dynamic stability[2,4]	Climb Level Descent	[illegible]	5800	[illegible]
Instrument flight operation performance[2,4]	Typical instrument flight tasks	[illegible]	[illegible]	[illegible]

[1] Tests conducted in the 8-TOW and 7-tube FWL mounted on wings configuration, mid range (FS 195.0) center of gravity using a main rotor speed of 324 RPM
[2] Stability and control augmentation system (SCAS) OFF
[3] Rotor static, hydraulic and electrical power provided by ground support equipment
[4] SCAS ON

RESULTS AND DISCUSSION

GENERAL

7. A quantitative and qualitative evaluation of instrument flight characteristics of the AH-1S (Prod) helicopter was conducted to infer potential for the AH-1S (ECAS) to meet the IMC qualification criteria established in Military Specification MIL-H-8501A (Ref 4, App A). The AH-1S (Prod) is not suitable for flight in instrument meteorogical conditions, which infers that the AH-1S (ECAS) will also not be suitable. Four deficiencies were identified: Unsatisfactory cyclic control system mechanical charateristics, large pitot-static system airspeed errors in climb and descent; easily excited lateral gust response; and vertigo inducing location of radio control panels. Additionally, seven shortcomings were noted: Persistant lateral-directional oscillations, lateral trim changes with airspeed, weak static longitudinal stability at cruise airspeed, an engine-torque oscillation, following a power change, location of Environmental Control System (ECS) control head, obstructed view of vertical index reference mark on pilot's attitude indicator, and the lack of storage space for instrument flight publications and equipment.

HANDLING QUALITIES

General

8. The AH-1S (Prod) tested shows a degradation in handling qualities from the previously tested AH-1G. The handling qualities classified as deficient are the cyclic control system mechanical characteristics which include objectional breakout plus friction force, a control force versus position gradient less than the breakout plus friction force, the existence of a trim control displacement band, and the easily excited lateral gust response. Shortcomings include the persistent lateral-directional oscillations and engine-torque oscillations that required in excess of 20 seconds for the engine power to stabilize.

Cyclic Control System Characteristics

9. Cyclic control system characteristics were measured in a static condition, as described in the Test Techniques section of Appendix D. Control force as a function of control displacement is presented in Figures 1 and 2, Appendix E, and summarized in Table 2. Control system characteristics in flight were qualitatively evaluated as being essentially the same as those observed under the static test conditions described above.

10. Prior to the test, cyclic friction (not adjustable from cockpit) was set to the manufacturer's value per maintenance instructions (Ref 9, App A). The longitudinal and lateral breakout force (including friction), control force versus position gradient, and limit control force all exceed both the limits specified in MIL-H-8501A and the approved deviations in the Bell Helicopter Textron detailed specification No. 209-997-398A, 5 October 1979 (Ref 10, App A).

11. The high longitudinal and lateral breakout forces, the control force position gradient and the large trim control displacement band all combine to preclude the smooth cyclic control movements necessary for precise aircraft attitude control required in IMC. The longitudinal and lateral breakout force (including friction) are objectional and require the pilot to operate across an 8-pound longitudinal and 6-pound lateral force differential for any modulated control displacement, such as

Table 2. Control System Characteristics[1]

Control	Direction	Breakout Force (Including Friction) (lb)		Control Force Versus Position Gradient (lb/in)		Limit Control Force (lb)		Trim Control Displacement Band Var[illegible]
		Test Results Pilot Station	MIL-H-8501A Maximum (Deviation[illegible])	Test Results Pilot Station	MIL-H-8501A Maximum	Test Results Pilot Station	MIL-H-8501A Maximum	Test Results Pilot Station
Longitudinal	Forward	4.0	1.5	2.5	2.0	16.0	8.0	1.5
	Aft	4.0	(2.25)			16.0		
Lateral	Left	[illegible]	1.5	[illegible]	[illegible]	16.0	[illegible]	[illegible]
	Right	[illegible]	(2.25)			[illegible]		

[illegible] ON
[illegible]
[illegible]
[illegible]

correcting a gust upset. This is fatiguing and when coupled with control force versus position gradient (2.5 pounds per inch) that is less than the breakout plus friction force, the result is a control displacement that more nearly resembles a step or spike input with frequent overshoot. The step or spike input occurs because the arm muscle does not readily accommodate the force discontinuity. The problem exists in both lateral and longitudinal axis and is further amplified by the frequency and severity of any gust upset. The existence of a trim control displacement band, of 1.5 inches longitudinally and 1.2 inches laterally, eliminates the force cue which would normally assist in returning the cyclic stick to the trim condition once it had been displaced. The effect of these unsatisfactory characteristics on the pilot's ability to control the aircraft is discussed more fully in paragraphs 24 through 40. The poor cyclic control system mechanical characteristics are a deficiency for IMC operation.

Control Positions in Trimmed Forward Flight

12. Control positions were determined in trimmed level, climbing, descending, and autorotational flight with the aircraft stabilized at zero sideslip for the conditions listed in Table 1, using the technique described in Appendix D. Test results are presented in Figure 3 (App F).

13. Longitudinal control position variations were essentially linear with airspeed and displayed increasing forward control with increasing airspeed. Lateral control position at the condition tested shows significant trim change with airspeed except for descending flight. These trim changes were particularly bothersome in level and climbing flight due to the non-linearity. A lateral control trim change of 0.7 inch occurred in level flight between 80 KCAS and 120 KCAS, while longitudinally that airspeed change required 1.1 inches of longitudinal control travel. The net result is an uncomfortable left forward movement of the cyclic at a 32° angle to the longitudinal axis of the aircraft. The lateral trim changes with power and airspeed are a shortcoming.

14. A persistent engine torque oscillation was excited each time engine power was changed. Figure A shows torque oscillations occurring at approximately three cycles per second. This persistent engine torque oscillation is an indication of engine-airframe incompatibility which may contribute to the excitation of the lateral-directional oscillation discussed in paragraph 23. The engine airframe incompatibility, as evidenced by the persistent engine torque oscillation, is a shortcoming.

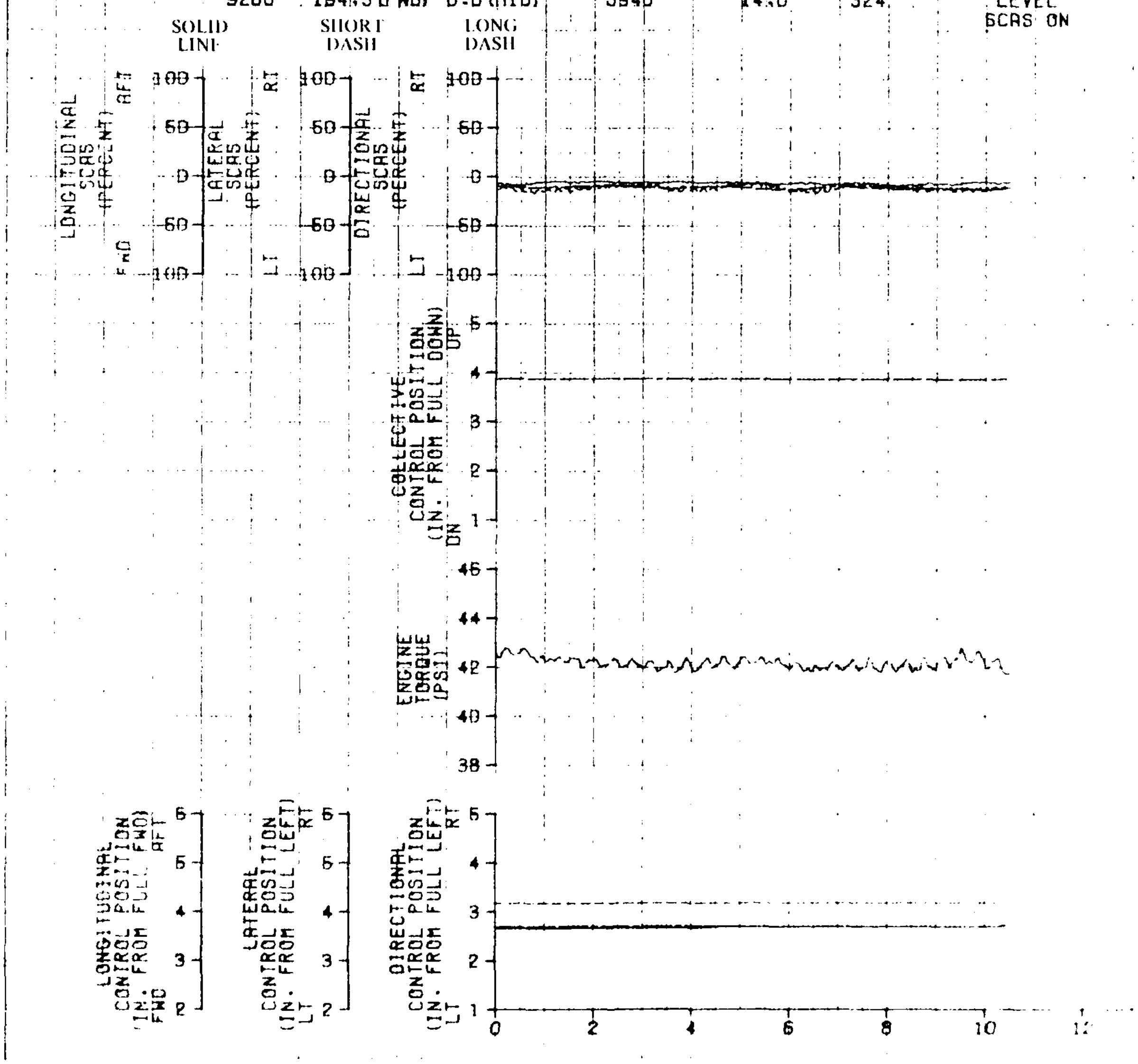
Static Longitudinal Stability

15. The static longitudinal stability characteristics were evaluated at the conditions specified in Table 1 with the aircraft stabilized at zero sideslip, using the technique described in Appendix D. Test results are presented in Figures 4 and 5, Appendix F.

16. The static longitudinal stability, as indicated by the variation of longitudinal control position with airspeed was stable at all trim airspeeds and conditions tested except in level flight at airspeeds greater than 125 KCAS. At speeds greater than the trim airspeed the gradient was nearly neutral. This weak static longitudinal stability, while meeting the minimum requirements of MIL-H-8501A, appeared neutral in flight and when coupled with the unsatisfactory cyclic control system characteristics required considerable pilot compensation (HQRS 5) to maintain a trim cruise airspeed. The weak static longitudinal stability at cruise airspeed is a shortcoming.

FIGURE A
ENGINE TORQUE OSCILLATIONS
AH-1S USA S/N 76-22579

GROSS WEIGHT (LB)	C.G. LOCATION LONG. (FS)	C.G. LOCATION LAT. (BL)	DENSITY ALTITUDE (FT)	OAT (C)	ROTOR SPEED (RPM)	FLIGHT CONDITION
9280	194.3 (FWD)	0.0 (MID)	5940	14.0	324	LEVEL SCAS ON



Static Lateral-Directional Stability

17. The static lateral-directional stability characteristics were evaluated at the conditions specified in Table 1 using the techniques described in Appendix D. Test results are presented in Figures 6 and 7, Appendix E.

18. Static directional stability was positive (increasing left directional control position with increasing right sideslip) throughout the sideslip envelope for all trim airspeeds and was satisfactory. Dihedral effect was also positive (increasing right lateral cyclic control position with increasing right sideslip) throughout the sideslip envelope for all trim airspeeds and is satisfactory. The side-force charactertistics are essentially the same as previously reported (Refs 3 and 11, App A). The static lateral-directional characteristics are satisfactory.

Dynamic Stability

19. Longitudinal and lateral-directional dynamic stability characteristics were evaluated at the conditions listed in Table 1. A description of each test technique is given in Appendix D. Selected time histories are presented in Figures 8 through 12, Appendix E.

20. The longitudinal short-term gust response was essentially deadbeat for all SCAS ON tests. SCAS OFF, the longitudinal pulse input excited the lateral-directional mode, and made the short-term response difficult to evaluate. The longitudinal short-term gust response, SCAS ON, met the requirements of MIL-H-8501A and is satisfactory for IMC flight.

21. A lateral-directional oscillation (Dutch roll) was the principle aircraft response to an external gust upset. Representative SCAS ON lateral-directional short-term gust response is shown in Figures 9 through 11, Appendix E. The aircraft exhibited positive but light damping in both roll and yaw. There was no tendency for the aircraft to return to steady, level flight once the roll and yaw rates subsided. This same characteristic was observed during the qualitative evaluation in gusty air. Roll attitude excursions of up to 10 degrees in the IMC environment were observed which are sufficient to interrupt the pilot's normal instrument cross check sequence, and resulted in the pilot concentrating on returning the aircraft to level flight. Since the aircraft is easily upset in roll, the requirement to concentrate on roll attitude control impacts on the pilot's ability to perform other flight tasks such as tuning radios, navigating, and maneuvering the aircraft during the approach phase of the flight. The lateral gust response of the AH-1S (Prod) is a deficiency for IMC operation.

22. The coupled lateral-directional oscillations with SCAS ON tend to persist following a gust upset. This characteristic was bothersome in the simulated IMC environment and precluded precise control of heading and roll attitude. This characteristic is most bothersome while maneuvering the aircraft in holding patterns, tracking from navigation aids to the airfield, and when complying with ground controlled approach (GCA) instructions. The existence of persistent lateral-directional oscillation fails to meet the requirements of paragraph 3.6.1.2 of MIL-H-8501A. The persistent lateral-directional oscillation characteristic is a shortcoming.

23. Spiral stability characteristics were evaluated SCAS ON and were found to be mildly divergent. Figure 12, Appendix E, is typical of the SCAS ON evaluation and

shows a 10 degree divergence at the end of 22 seconds. The SCAS OFF spiral excitation resulted in oscillatory roll divergence. The SCAS OFF spiral stability characteristics were difficult to evaluate due to excitation of the short term lateral-directional oscillation. The SCAS ON spiral stability characteristics are satisfactory.

QUALITATIVE ASSESSMENT

General

24. Simulated IMC maneuvers were evaluated from the pilot's position with side curtains installed. All external visual reference was eliminated, however the curtains were light enough to furnish full daylight lighting of the cockpit. The IMC simulation was separated into three distinct categories: First, an evaluation of basic air maneuvers and individual IMC tasks; second, NAVAID approaches; and third, a representative IFR flight. The performance standards used were those normally associated with an annual instrument checkride (±100 feet altitude, ±10 knots indicated airspeed (KIAS), and ±10° heading). Additionally, the pilot's workload was qualitatively assessed throughout all flights. Six pilots participated in the qualitative evaluation. Based on the inability to meet performance standards and excessively high pilot workload, the AH-1S (Prod) is considered unsuitable for IMC flight.

Basic Instrument Meteorological Conditions (IMC) Tasks

25. Each individual task was evaluated with the pilot's total attention devoted to aircraft control for the purpose of achieving the desired performance standard. No distractors, such as navigation radio tuning or communication with controllers, were performed. All tasks were performed in both smooth air and in light turbulence with aircraft at mid cg and maximum gross weight at takeoff.

Straight and Level Flight:

26. The first task was to perform straight and level flight. The aircraft gust response was primarily in roll with some minor accompanying yaw. The roll attitude changed as much as ten degrees from the trim condition and constantly required lateral cyclic inputs to regain a wings-level attitude. The cyclic inputs were small, however, they were within the trim control friction band, and a precise return of the cyclic to the original trim condition was not possible. Due to the high breakout plus friction forces required to displace the cyclic and the comparatively low force gradient, lateral control inputs resulted in overshooting the desired control position. Straight and level flight could be performed within the desired performance standard, but required constant attention and frequent control inputs to achieve that performance (HQRS 5). Throughout the straight and level evaluation, continuous lateral-directional oscillations were noted (paragraph 22). These were sufficient to cue the pilot to make control inputs which added to the already high workload.

Standard Rate Level Turns:

27. Turns were made both left and right at 90 and 110 KIAS. The [illegible] bank angle for a standard rate turn was 20 degrees. In each case, gust disturbances made control of the bank angle extremely difficult with bank angle frequently varying

from 15 to 30 degrees. The undesirable mechanical characteristics (paragraph 11) contributed to the difficulty of performing the standard rate turns. The established standard was achievable; however, there was a high pilot workoad associated with the task (HQRS 6) and variations of 80 feet on assigned altitude were frequent. The desired rollout heading could be acquired within 10 degrees (HQRS 6).

Constant Heading Climbs and Descents:

28. Climbs and descents were initiated from trimmed level flight conditions at 90 and 110 KIAS. The desired vertical speed was 500 feet per minute. When power was added, the airspeed immediately showed an increase on the pilot's indicator. To correct the apparent airspeed variation, aft cyclic was applied. The pitch attitude also indicated a slight nose up change and the rate of climb went rapidly through the 500 feet per minute condition and reached approximately 1200 feet per minute. The power was then reduced in an effort to establish the desired rate of climb. On reduction of power, the reverse affect was noted in that indicated airspeed immediately decreased indicating a requirement for forward cyclic and with the new power setting produced a climb rate well below the target 500 feet per minute. These factors were also evident when a level off at a predetermined altitude was performed. It was not possible to consistently level off within 100 feet of the desired altitude, and errors as much as 200 feet were experienced. In a 500-foot change in altitude, it was not possible to achieve a stabilized 500 feet per minute rate of climb and continue to meet performance standards (HQRS 7). Figure 13, Appendix E, is a time history comparison between ship's and boom airspeed system. The pilot held the ship indicated airspeed constant while adding power. The boom system slowed 12 knots while the indicated airspeed remained essentially unchanged. The large airspeed position error due to the influence of power on the pitot static system is a deficiency for IMC flight.

29. There was an additional factor which contributed to the difficulties associated with stabilizing the aircraft in a steady climb. The cyclic trim control positions have substantial lateral changes with airspeed and power. These lateral cyclic requirements occur with a control system that has undesirably high breakout plus friction forces. The result was that lateral cyclic position was constantly changing throughout the maneuver due to airspeed and power variations. This increased the pilot workload and was part of the reason satisfactory performance could not be achieved. Large lateral trim changes with power and airspeed are a shortcoming previously discussed (paragraph 13).

Climbing and Descending Standard Rate Turns.

30. Climbing and descending turns were initiated from trimmed level flight at 90 KIAS. The difficulties identified in previous maneuvers were also evident here. The lateral gust response of the aircraft made bank angle control a constant problem. The bank angle could not be controlled within 10 degrees. The same pitot-static problems discussed above existed and, when combined with attitude control, made basic aircraft control extremely difficult and required the pilot's maximum attention (HQRS 8).

31. The attitude indicator is recessed in the instrument panel in front of the pilot. There are reference marks at 0 (vertical point), 10, 20, 30, and 45 degree bank positions. The vertical reference is an inverted triangle easily distinguished from the other reference marks which are merely short reference lines of uniform thickness. A

full pilot loses the distinctive triangular identification of the vertical reference due to the obstruction of the broad portion of the triangle caused by the recessed instrument in its case. The loss of this reference in turns slows the pilot's cross check since a quick mental calculation must be made to find the vertical reference. The obstruction of the vertical reference portion of the attitude indicator by the instrument case is a shortcoming.

Holding

32. A holding pattern was preplanned prior to flight. A radial at a VOR station was identified and a teardrop entry into a standard holding pattern was selected. The VOR was pretuned and the pilot's entire attention was devoted to maintaining a holding pattern. There were four completed holding circuits performed during which frequent variations of up to ±80 feet altitude, ±10 degrees bank angle, and ±10 degrees heading were experienced. The pilot devoted his complete effort to achieve that result (HQRS 6) and was not able to establish wind correction and adjust for a one minute inbound leg.

NAVAID Approaches

VOR Approach

33. A complete VOR approach was performed to include transition to the station, a procedure turn, and descent to minimum descent altitude (MDA). The same undesirable flight characteristics previously discussed persisted throughout the maneuver. Pitot-static errors were noted at the initiation of the descending procedure turn and also after passing the station on final approach. These adversely impacted on the ability to establish the desired rate of descent and were also seriously distracting when power was added on reaching descent limit. The power addition resulted in an apparent increase in airspeed which required correction by the pilot. A high pilot workload condition at this point [illegible] could distract the pilot from his primary task of transitioning to the runway environment or maintaining the aircraft at MDA until missed approach was required. The desired performance was achieved, however, the pilot workload is considered unacceptable (HQRS 7).

Ground Controlled Approach

34. A surveillance approach was performed using Army ground approach facilities and a precision approach was simulated by the further addition of glide slope information to the pilot. In both cases, satisfactory performance could be achieved; however, the previous problems of poor mechanical characteristics, and gust response, pitot-static errors, and persistent lateral-directional oscillations continued to produce a high pilot workload. The ground controlled approach when compared to the VOR previously discussed, reduced the pilot's cross-check requirements and resulted in some reduction in workload (HQRS 6).

Tactical Approach

35. The tactical approach was not performed [illegible]

the AH-1S (Prod) are such that the aircraft consistently drifts off speed. In descending turns a desired bank angle of 20 degrees was attempted. During one point in a descending turn, the bank angle reached 40 degrees before it was corrected by the pilot. The roll response to gusting conditions made descending turns extremely difficult and in combination with pitot-static errors and poor mechanical characteristics made satisfactory achievement of the desired standards impossible. The pilot's total concentration was devoted to maintaining aircraft control (HQRS 8).

SIMULATED IFR FLIGHT

36 The flight was conducted in simulated IMC conditions and was controlled by the approach control facility serving the area. All routine communications associated with an IFR flight were performed. The gunner made some of the radio calls and was also responsible for copying clearances. He did not fly the aircraft at any time during the IMC simulation due to the limited navigation and flight instruments as well as the poor flight control characteristics at the gunner's station. All radios and navigation equipment were pretuned prior to takeoff. The general flight scenario was radar vectors to a VOR radial, intercept, tracking to the VOR station, holding, and terminating with a VOR approach.

37 The first problem encountered was retuning the UHF communications radio. All tuning was performed by the pilot since all control heads are located in the aft cockpit. Control head location is shown in the operator's manual (Ref 5, App A). In order to tune the UHF radio, the pilot had to exchange hands on the cyclic and look down and to the right to see the frequency numbers. With his hand on the selector, his view of the frequency was obscured. During the brief time that it took to change the hundreds digit of the frequency, the aircraft had rolled off heading approximately 10 degrees and was in a turn. Three more similar occurrences were experienced before a new UHF frequency was finally set. Once the frequency was set, the pilot made the communication or alternatively advised the copilot a new frequency was now tuned. Similar experiences were noted when VOR frequency and transponder code changes were required. The transponder control head location was particularly bad in that it is adjacent to the pilot's right hip. This location made reading the code setting very difficult and necessitated head movements which produced vertigo. The sensation of vertigo increased the difficulty of returning the aircraft to a level trim condition after tuning the transponder code. The vertigo inducing location of the UHF, VOR, ADF, and transponder control heads is considered a deficiency for IMC flight.

38 During the course of the flight the cockpit temperature became uncomfortably warm. The pilot attempted to adjust the environmental control system (ECS) located on the right side panel aft of the transponder. The control location is shown in the operator's manual (Ref 5, App A). Again during this distraction performance standards could not be met and the tendency for vertigo was even more disconcerting to the pilot. Actual temperature adjustment is not absolutely essential for IMC operations, but it is frequently necessary to activate the rain removal switch which is located on the same control head producing the same result. The vertigo-inducing location of the ECS control head and rain removal switch is a shortcoming for IMC operations.

39. Basic navigation was extremely difficult in that the tuning of navigation radios and orienting charts resulted in the pilot exceeding the established performance standards consistently. Very little assistance was possible from the gunner since he could not see what frequencies were tuned and was unable to retune to establish location by intersection. Due to the tandem seating arrangement, he was unable to assist in setting up the necessary approach plate and was limited to monitoring pertinent approach information and advising the pilot periodically during the approach. The AH-1S (Prod) in its present configuration is therefore basically a single pilot IMC aircraft. These difficulties were further complicated by the lack of storage space in the cockpit. The necessary charts and approach plates could not be organized effectively. Lack of storage space in the cockpit area is a shortcoming.

40. During the VOR holding and VOR approach portion of the flight, routine IFR tasks created a workload sufficient to cause the pilot to fail to meet performance standards consistently. Changing the course setting on the horizontal situation indicator (HSI) and selecting the desired function on the HSI control panel took enough time and caused sufficient distraction that heading and attitude changes occurred prior to reestablishing a cross check of flight instruments. Any requirements in excess of basic aircraft control taxed the pilot beyond his capabilities.

CONCLUSIONS

GENERAL

41. The AH-1S (Prod), and by inference, the AH-1S (ECAS) are not considered suitable for flight in Instrument Meteorological conditions.

DEFICIENCIES

42. The following deficiencies associated with flying the AH-1S (Prod) in IMC were identified:

a. The poor cyclic control mechanical system characteristics (paragraph 11)

b. Large airspeed position error due to the influence of power on the pitot-static system (paragraph 28)

c. The easily excited lateral gust response (paragraph 21)

d. Vertigo-inducing location of the UHF, VOR, ADF, and transponder control heads (paragraph 37).

SHORTCOMINGS

43. The following shortcomings associated with flying the AH-1S (Prod) in IMC were identified:

a. The persistent lateral-directional oscillation (paragraph 22)

b. The lateral trim change with airspeed and power (*paragraph 13*)

c. The weak static longitudinal stability at cruise airspeed (paragraph 16)

d. The engine/airframe incompatibility (paragraph 14)

e. Vertigo-inducing location of the ECS control head and rain removal switch (paragraph 38)

f. Obstruction of the vertical reference mark on the attitude indicator (paragraph 31)

g. Lack of storage space in the cockpit area (paragraph 39).

SPECIFICATION COMPLIANCE

44. Within the scope of this test, the AH-1S (Prod) helicopter failed to meet the following requirements of military specification MIL-H-8501A

a. Paragraph 3.2.6 - Longitudinal control full throw forces exceed the 8.0 pound limit by 8.0 pounds forward and aft, (100 percent) (paragraph 11)

b. Paragraph 3.2.7 - Longitudinal control breakout force (including friction) exceeded the 1.50 lb maximum by 2.5 lbs (167 percent). Also failed to meet authorized deviation (Ref 10, App A) (paragraph 10)

c. Paragraph 3.3.12 - Lateral control full throw forces exceed the 7.0 pound limit by 9.0 pounds left and right (130 percent) (paragraph 10)

d. Paragraph 3.3.13 - Lateral control breakout force (including friction) exceeded the 1.50 lb maximum by 1.5 lbs (100 percent). Also failed to meet authorized deviation (Ref 10, App A) (paragraph 10)

e. Paragraph 3.6.1.1 - The aircraft exhibited a persistent lateral-directional oscillation (paragraph 22).

RECOMMENDATIONS

45. The deficiencies identified in paragraph 42 must be corrected prior to operation in IMC.

46. The shortcomings identified in paragraph 43 should be corrected prior to operation in IMC.

APPENDIX A. REFERENCES

1. Final Report, US Army Aviation Systems Test Activity (USAASTA), Project No. 72-29, *Instrument Flight Evaluation AH-1G*, July 1975.

2. Letter, US Army Aviation Research and Development Command (AVRADCOM), DRDAV-EQI, 5 May 1979 (with revision 6 June 1979), subject: AH-1S Airworthiness and Flight Characteristics Test for Instrument Flight.

3. Final Report, US Army Aviation Engineering Flight Activity (USAAEFA) Project No. 78-03, *Preliminary Airworthiness Evaluation, AH-1S Helicopter Installed with Enhanced Cobra Armament System (AH-1S/ECAS)*, February 1979.

4. Military Specification, MIL-H-8501A, *Helicopter Flying and Ground Handling Qualities, General Requirements For*, 7 September 1961, with Amendment 1, 3 April 1962.

5. Technical Manual, TM 55-1520-236-10, *Operator's Manual, Army Model AH-1S (Prod), AH-1S (ECAS), AH-1S (Modernized Cobra) Helicopter*, 31 January 1980, with change 2, May 1980.

6. Letter, AVRADCOM, DRDAV-EQI, 25 April 1980, subject: Airworthiness Release for Evaluation of the AH-1S Helicopter for Flight in Instrument Meteorological Conditions (IMC).

7. Flight Test Manual, Naval Air Test Center, FTM No. 101, *Helicopter Stability and Control*, 10 June 1968.

8. Aircrew Training Manual, TC 1-136, *Attack Helicopter, AH-1*, Change 3, August 1979.

9. Technical Manual, TM 55-1520-236-23-2, *Aviation Unit and Intermediate Maintenance Manual, Army Model AH-1S (Prod), AH-1S (ECAS), AH-1S (Modernized Cobra) Helicopters*, 8 May 1980, with change 1, October 1980.

10. Detail Specification, Bell Helicopter Textron, No. 209-947-308A, 5 October 1979.

11. Final Report, USAASTA, Project No. 72-30, *Engineering Flight Test, AH-1G Helicopter with Model 212 Tail Rotor, Part II, Performance and Handling Qualities*, September 1973.

12. Army Regulation 310-25, Headquaters, Department of the Army, *Dictionary of United States Army Terms*, September 1975.

APPENDIX B. AIRCRAFT DESCRIPTION

GENERAL

1. The test helicopter, S/N 76-22573, was a production AH-1S with the K747 main rotor blades installed. Wing stores configuration for all tests were two TOW launchers on each of the outboard wing stores stations and one 7-tube lightweight launcher pod on each of the inboard wing stores stations.

MAIN ROTOR BLADES

2. The K747 main rotor blades utilize a multicell filament wound fiberglass spar, a nomex honeycomb core afterbody, and a Kevlar trailing edge spline, all enclosed by fiberglass skin. At the inboard end, cheekplates carry loads to an aluminum adapter which is attached to the hub with a pin.

3. The K747 blade airfoil shape is based on a family of airfoils developed by Boeing Vertol. The airfoil shape varies from blade tip to root as follows:

r/R (Blade Radius Station)	Airfoil Design
From tip to 0.85	K747 8% thick Boeing Vertol VR-8
From 0.85 to 0.67	Linear transition to 12% thick Boeing Vertol VR-7
From 0.67 to 0.25	12% thick Boeing Vertol VR-7
From 0.25 to 0.18	Gradual buildup to 25% thick by cheekplates

ENGINE AND TRANSMISSION/TAIL ROTOR DRIVE

4. The T53-L-703 turboshaft engine is installed in the AH-1S (Prod) helicopter. This engine employs a two-stage, axial-flow free power turbine, a separate two-stage, axial flow turbine driving a five-stage axial and one-stage centrifugal compressor, variable inlet guide vanes, and an external annular combustor. A 3.2105:1 reduction gear box located in the air inlet housing reduces power turbine speed to a nominal output shaft speed of 6600 RPM at 100 percent N_2. The engine reduction gear box is limited to 1175 foot-pounds (ft-lb) torque for 30 minutes and 1110 ft-lb torque for continuous operation. A T_5 interstage turbine temperature sensor harness measures interstage turbine temperatures and displays this information in the cockpit as turbine gas temperature on the cockpit instruments.

5. The main transmission has a 1290 SHP limit for 30 minutes and a 1134 SHP limit for continuous operation at a rotor speed of 324 RPM (100 percent N_R). The aircraft is further limited to 88 percent torque above 100 KIAS. The tail rotor drive system has a 260 SHP transient limit for 4 seconds and a 187 SHP limit for continuous operation. The engine used during this test was serial number LE 13145Z.

PRINCIPAL DIMENSIONS AND GENERAL DATA

6. The principal dimensions and general data concerning the AH-1S (Prod) helicopters are as follows.

Overall Dimensions

Length, rotor turning	53 feet, 1 inch
Height, tail rotor vertical	13 feet, 9 inches
Length, rotors removed	44 feet, 7 inches

Main Rotor

Diameter	44 feet
Disc area	1520.5 ft^2
Number of blades	2
Blade twist	-0.556 degrees
Airfoil	See paragraph 3

Tail Rotor

Diameter	8 feet, 6 inches
Disc area	56.75 ft^2
Solidity	0.1436
Number of blades	2
Blade chord, constant	11.5 inches
Blade twist	0.0 degrees
Airfoil	NACA 0018 at the blade root changing linearly to a special cambered section at 8.27 percent of the tip

Fuselage

Length:	44 feet, 7 inches
Height:	
To tip of tail fin	10 feet, 8 inches
Ground to top of mast	12 feet, 3 inches
Ground to top of transmission fairing	10 feet, 2 inches
Width	
Fuselage only	3 ft
Wing span	10 feet, 9 inches
Skid gear tread	7 ft
Elevator:	
Span	6 feet, 11 inches
Airfoil	Inverted Clark Y

Vertical Fin:

Area	18.5 ft^2
Airfoil	Special cambered
Height	5 feet, 6 inches

Wing:

Span	10 feet, 9 inches
Incidence	17 degrees
Airfoil (root)	NACA 0030
Airfoil (tip)	NACA 0024

Weight and Balance

7. The aircraft weight, longitudinal CG location and lateral CG location were determined prior to testing. A fuel cell calibration was also performed prior to testing. All weighings were accomplished with instrumentation installed without external stores or chin turret weapons installed.

APPENDIX C. INSTRUMENTATION

1. In addition to the standard aircraft instruments, calibrated instruments were displayed at the pilot and gunner cockpit panels. Data were obtained from cockpit instruments and from the test instrumentation system. The test instrumentation system was installed, calibrated, and maintained by USAAEFA personnel. All test instrumentation parameters are encoded pulse code modulation (PCM) and recorded on magnetic tape aboard the test aircraft. Sideslip vane, angle-of-attack vane, total temperature sensor, and pivoting pilot-static head are located on a test boom mounted on the nose of the aircraft.

2. The parameters recorded on magnetic tape are:

PCM Parameters

Time code
Event
Flight number
Run number
Main rotor speed
Fuel temperature
Fuel used
Engine fuel flow rate
Engine gas producer speed
Engine power turbine speed
Airspeed (boom system)
Airspeed (ship's system)
Altitude (boom system)
Altitude (ship's system)
Total air temperature
Angle of attack
Angle of sideslip
Engine torque
Engine exhaust gas temperature
Control positions
    Longitudinal
    Lateral
    Directional
    Collective
Aircraft attitudes
    Pitch
    Roll
Aircraft angular rates
    Pitch
    Roll
    Yaw
Main rotor shaft torque
Main rotor blade angle

3. The parameters displayed in the cockpit are:

Pilot Panel

Pressure altitude (boom system)
Pressure altitude (ship's system)

Airspeed (boom system)
Airspeed (ship's system)
Main rotor speed
Engine torque
Engine turbine gas temperature
Engine gas producer speed
Angle of sideslip

Copilot Panel

Pressure altitude (boom system)
Airspeed (boom system)
Main rotor speed
Engine torque
Engine gas producer speed
Total air temperature
Fuel used
Time code display
Data system control

4. The calibrated instrumentation displayed at the pilot's station was used throughout the handling qualities phase of the test. The pilot's instrument panel was returned to the standard Cobra configuration (Ref 5, App A) for the test flights involving IMC maneuvers and evaluation.

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. Established test techniques and data analysis methods were used in the handling qualities tests. Descriptions of the test techniques are contained in this appendix. The Handling Qualities Rating Scale, presented in Figure 1, was used to augment pilot comments relative to handling qualities. Definitions of deficiencies and shortcomings are as stipulated in Army Regulation 310-25 (Ref 11, App A). Control positions in trimmed forward flight, static longitudinal stability, and dynamic stability tests were conducted at zero sideslip; all other tests were conducted in coordinated flight (ball centered).

WEIGHT AND BALANCE

2. The aircraft weight, longitudinal CG location, and lateral CG location were determined prior to testing, and checked periodically throughout the tests. The weighing was accomplished with instrumentation installed. The aircraft was ballasted as necessary to achieve the desired takeoff gross weight and CG.

HANDLING QUALITIES

Cyclic Control System Characteristics

3. The mechanical characteristics of the control system were evaluated on the ground with the rotor and engine stopped. Hydraulic and electrical power were provided by external sources. Control forces were measured by use of a hand-held force gage applied at the pilot's cyclic grip, one finger detent below the trigger guard. A three- to five-second data record was taken of control position while control forces were hand recorded. All switches and systems were set to duplicate normal in-flight conditions. Control displacements from the neutral trim point were then plotted as a function of force.

Control Positions in Trimmed Forward Flight

4. Control positions in trimmed forward flight at zero sideslip were determined by stabilizing the helicopter on a constant heading and airspeed. Data were recorded on magnetic tape. Control positions were plotted as a function of airspeed.

Static Longitudinal Stability

5. Static longitudinal stability was evaluated in level, climbing, and autorotational flight. The aircraft was trimmed at the desired trim airspeed. With collective fixed, the aircraft was stabilized at approximately 5-knot increments ±15 knots from trim airspeed, allowing altitude, rate of climb, or rate of descent to vary as necessary. Control positions and airspeeds were recorded on magnetic tape. The control positions were then plotted as a function of calibrated airspeed.

Static Lateral-Directional Stability

6. This test was conducted using the steady-heading sideslip method and was accomplished by establishing a trimmed flight condition and then stabilizing at sideslip angles, in 5-degree increments, to the limit of the flight envelope or until full

control deflection was reached, whichever occurred first. Collective control position was fixed at the trim value and altitude was allowed to vary. The trim airspeed and desired heading were maintained. All pertinent parameters were recorded on magnetic tape. The static directional stability, dihedral effect, and side-force characteristics of the aircraft were evaluated by plotting the variation of control position and aircraft attitude as a function of sideslip angle.

Dynamic Stability

7. Dynamic stability tests were conducted to evaluate the short and long-period response characteristics of the aircraft. Short-period characteristics were evaluated to determine aircraft response to sudden wind gusts and were simulated by rapidly displacing the cyclic control approximately one inch, holding the input for 0.5 second, then rapidly returning the control to the trim position while recording the resulting aircraft responses on magnetic tape. Lateral-directional short-term response was further evaluated by directional control doublets.

8. Longitudinal long-period characteristics were evaluated to determine the aircraft's tendency to return to a trim condition after being disturbed. The long-period response was excited by stabilizing the aircraft on a trim condition with force trim ON and then displacing the longitudinal control forward or aft to effect an airspeed change of approximately 10 knots. The control was then returned to trim, and the resulting aircraft response was recorded on magnetic tape. During the response, controls were held fixed, but slight pressures directionally and laterally were used to maintain a constant heading and laterally level attitude. The long-period response was evaluated at three trim airspeeds, and a positive and negative airspeed change was tested for each point.

SIMULATED IMC FLIGHT

9. Simulated IMC flight was conducted to qualitatively evaluate pilot workload. Workload in the IMC environment was determined by selecting a task and performance standard, (Ref 8, App A) and then assigning a HQRS number (Figure 1) based on the amount of pilot compensation necessary to achieve the standard. The performance standards used were ±100 feet altitude, ±10 KIAS, and ±10° heading. All tasks were performed from the pilot cockpit with all external outside reference eliminated, and no assistance from the gunner.

APPENDIX E. TEST DATA

INDEX

FIGURE 1
LONGITUDINAL CONTROL SYSTEM CHARACTERISTICS
AH-1S USA S/N 76-22573

NOTES:
1. ROTOR STATIC
2. HYDRAULIC AND ELECTRICAL POWER PROVIDED BY GROUND UNITS.
3. LATERAL CONTROL POSITION CENTERED DURING TEST.
4. CONTROL FORCES MEASURED AT CENTER OF GRIP.
5. FORCE TRIM ON
6. TOTAL LONGITUDINAL CONTROL TRAVEL = 10.1 INCHES

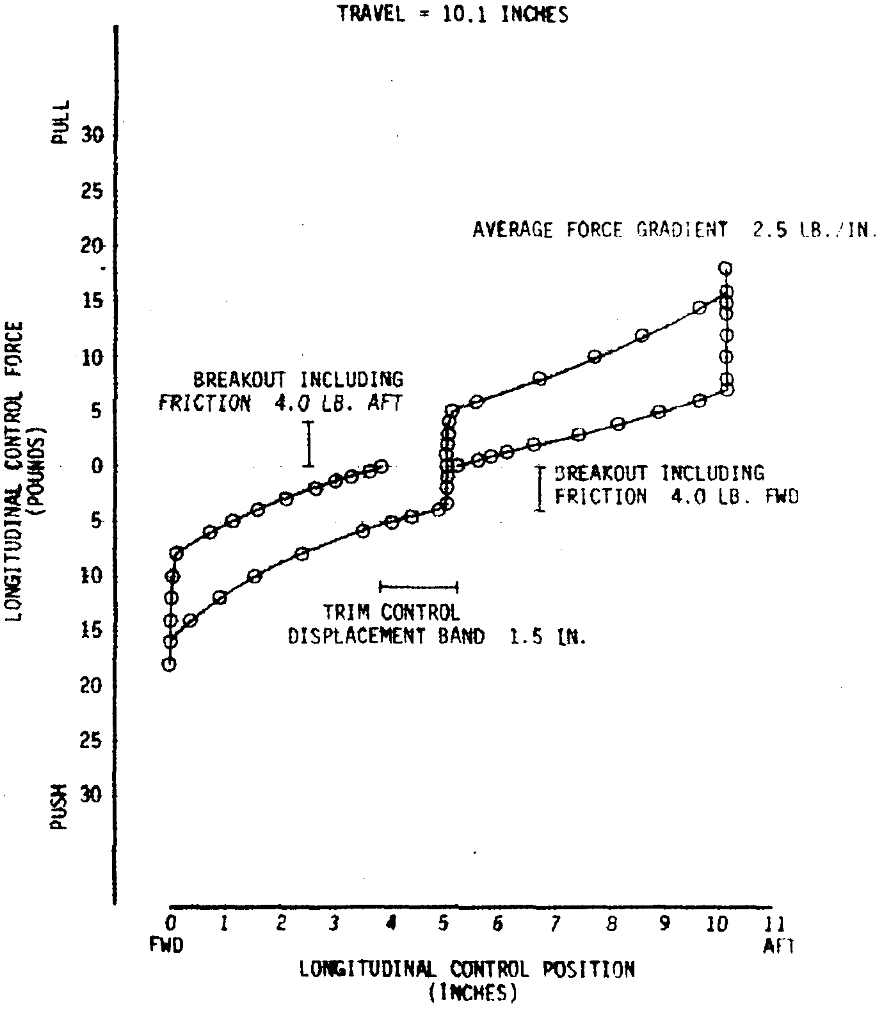


FIGURE 2
LATERAL CONTROL SYSTEM CHARACTERISTICS
AH-1S USA S/N 76-22573

NOTES:
1. ROTOR STATIC
2. HYDRAULIC AND ELECTRICAL POWER PROVIDED BY GROUND UNITS
3. LONGITUDINAL CONTROL POSITION CENTERED DURING TEST
4. CONTROL FORCES MEASURED AT CENTER OF GRIP
5. FORCE TRIM ON
6. TOTAL LATERAL CONTROL TRAVEL = 8.5 INCHES

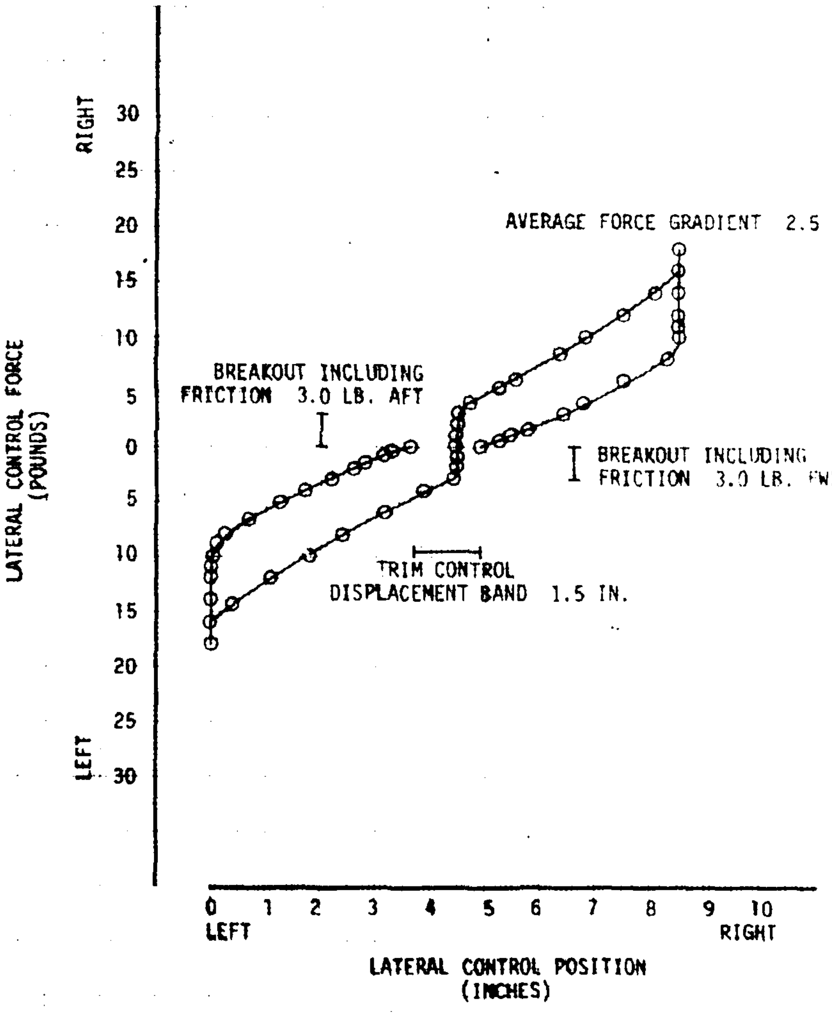


FIGURE 3
CONTROL POSITIONS IN TRIMMED FLIGHT
AH-1S USA S/N 76-22573

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION
○	9660	194.7(FWD)	0.0(MID)	5980	11.0	324	LEVEL
□	9440	194.5(FWD)	0.0(MID)	6100	11.0	324	MCP CLIMB
◇	9420	194.5(FWD)	0.0(MID)	5720	11.0	324	DESCENT
△	9140	194.2(FWD)	0.0(MID)	5260	11.0	324	AUTOROTATION

NOTE: 1. TWO M65 4-TOW AND TWO M261 LWL MOUNTED ON WINGS.
2. ZERO SIDESLIP
3. SCAS ON.

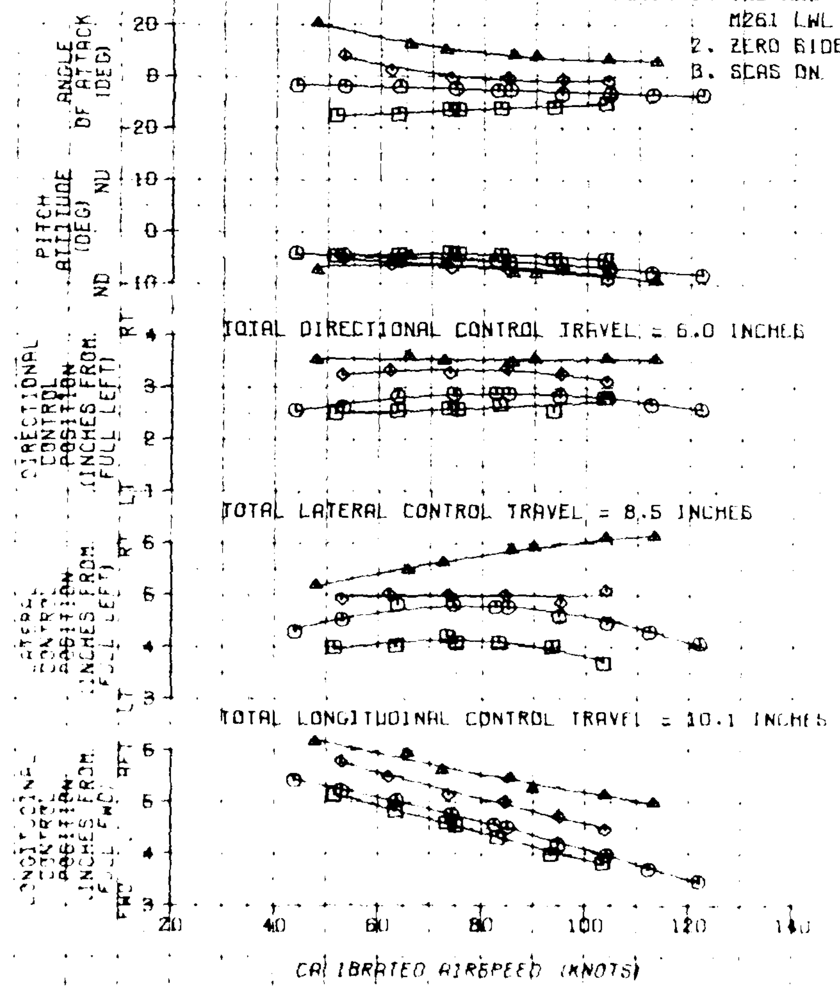


FIGURE 4
COLLECTIVE FIXED STATIC LONGITUDINAL STABILITY
AH-1S USA S/N 76-22573

	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM CALIBRATED AIRSPEED (KTS)
□	8940	194.0 (FWD)	0.0 (MID)	8340	9.5	324	MCP CLIMB	70
◇	8880	193.9 (FWD)	0.0 (MID)	7400	8.0	324	AUTOROTATION	50
▲	9700	194.7 (FWD)	0.0 (MID)	6600	16.0	324	DESCENT	70
⊕	9540	194.6 (FWD)	0.0 (MID)	6300	17.0	324	DESCENT	100

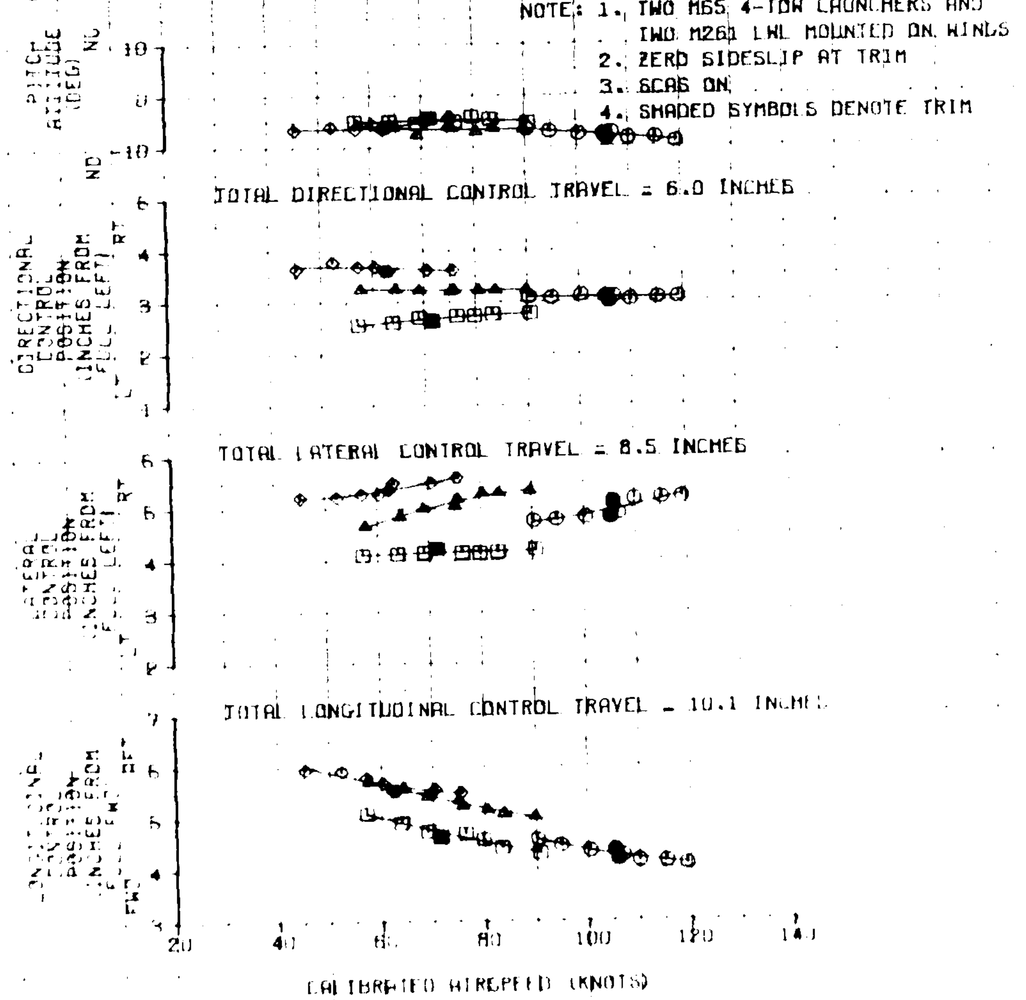


FIGURE 5

COLLECTIVE FIXED STATIC LONGITUDINAL STABILITY

AH-1S USA S/N 76-22573

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION	TRIM CALIBRATED AIRSPEED (KTS)
8800	193.8(FWD)	0.0(MID)	5200	12.0	324	LEVEL	120

NOTE: 1. TWO M65 4-TOW LAUNCHERS AND TWO M261 LWL MOUNTED ON WINGS
2. ZERO SIDESLIP AT TRIM
3. SCAS ON.
4. SHADED SYMBOLS DENOTE TRIM

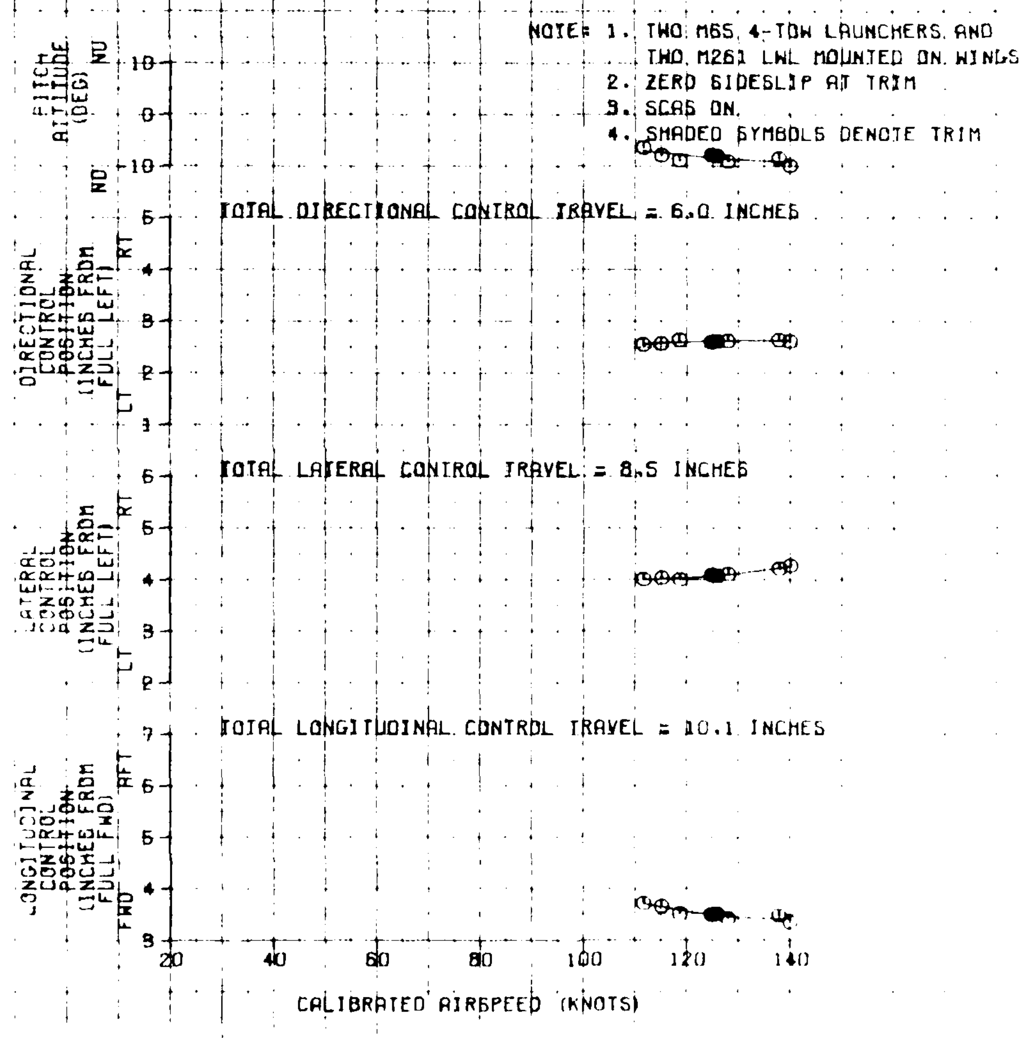


FIGURE 6
STATIC LATERAL-DIRECTIONAL STABILITY
AH-1S USA S/N 76-22573

	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION
□	9620	194.6(FWD)	0.0(MID)	6460	13.5	324	CLIMB 74 KCAS
◇	9560	194.6(FWD)	0.0(MID)	6320	13.5	324	DESCENT 105 KCAS
△	9400	194.5(FWD)	0.0(MID)	6440	13.5	324	AUTOROTATION 64 KCAS

NOTE: TWO M65 4-TOW LAUNCHERS AND TWO M260 LWL MOUNTED ON WINGS

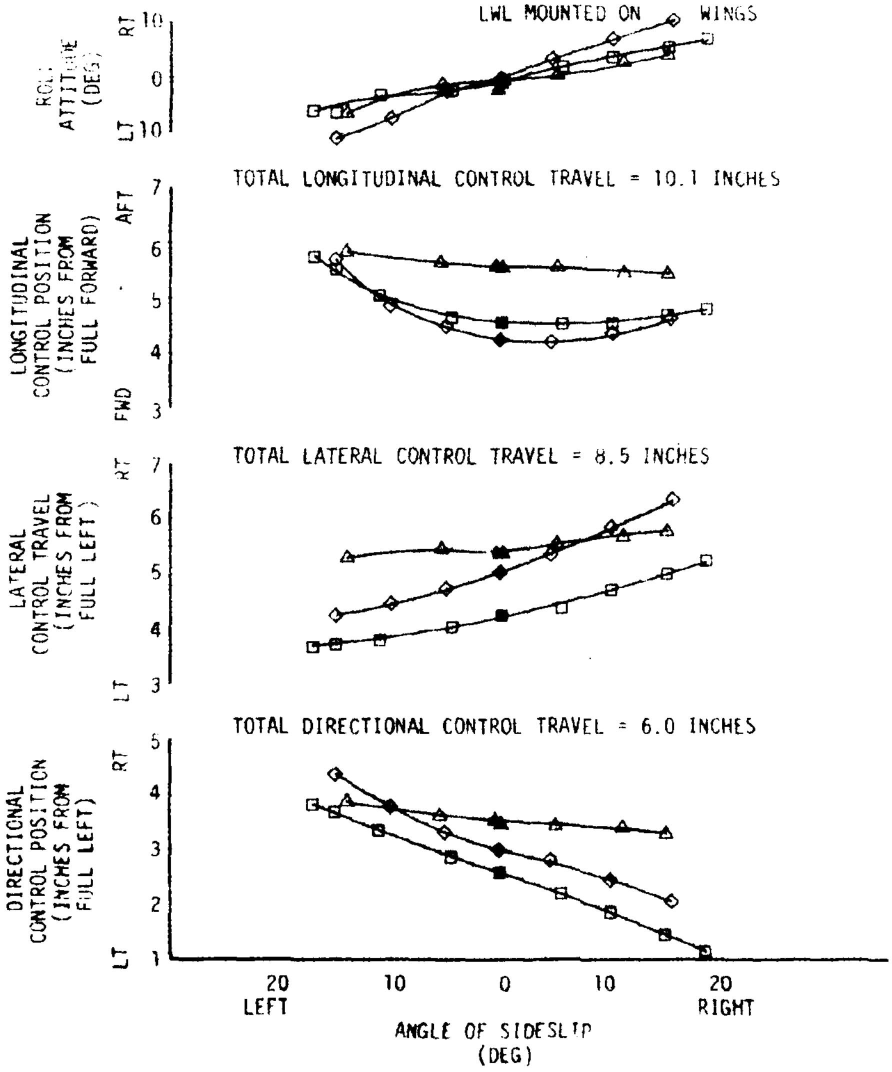


FIGURE 7
STATIC LATERAL-DIRECTIONAL STABILITY
AH-1S USA S/N 76-22573

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION
9780	194.7(FWD)	0.0(MID)	6140	13.0	324	LEVEL

NOTES: 1. TRIM CALIBRATED AIRSPEED 115 KNOTS
2. TWO M65 4-TOW LAUNCHERS AND TWO M260 LWL MOUNTED ON WINGS

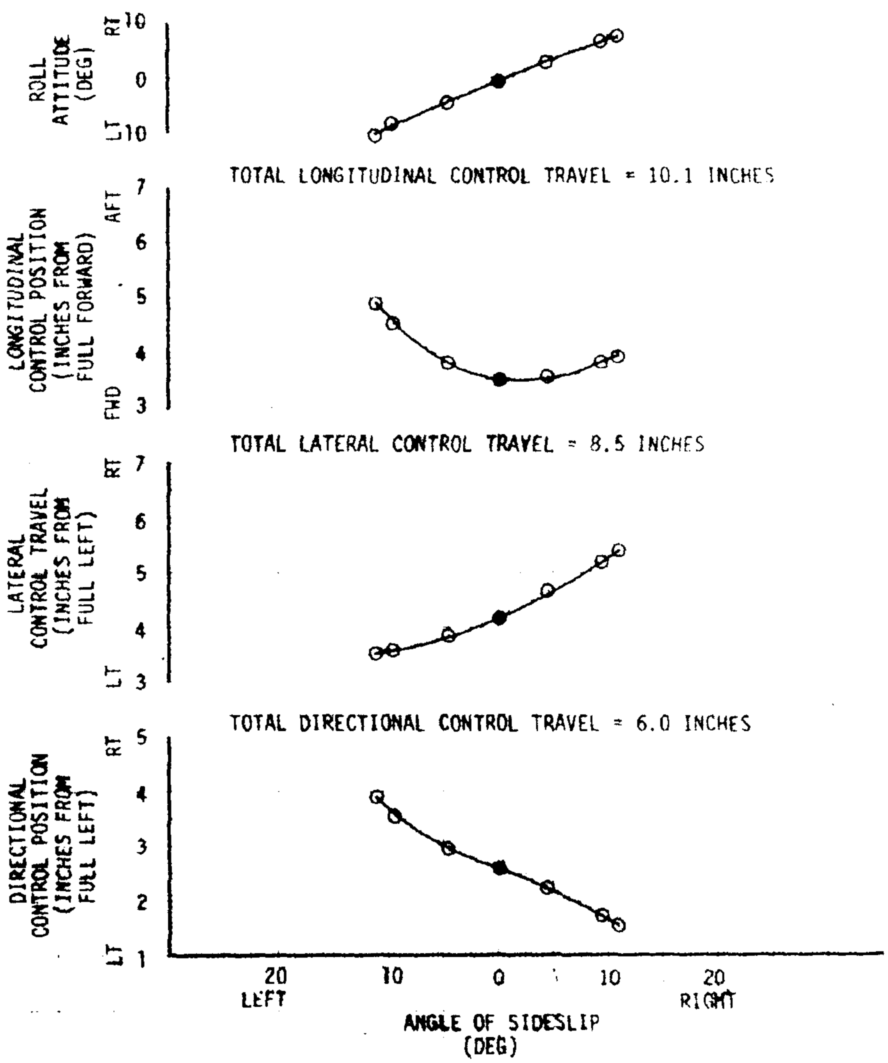


FIGURE 8
LONGITUDINAL SHORT TERM RESPONSE
AH-1S USA S/N 76-22573

GROSS WEIGHT (LB)	C.G. LOCATION LONG. (FS)	C.G. LOCATION LAT. (BL)	DENSITY ALTITUDE (FT)	OAT (C)	ROTOR SPEED (RPM)	FLIGHT CONDITION
9080	94.1 (FWD)	0.0 (MID)	6340	2.5	324	DESCENT SCAS ON

NOTE: TWO M65 4-TON AND TWO M261 LNL MOUNTED ON WINGS

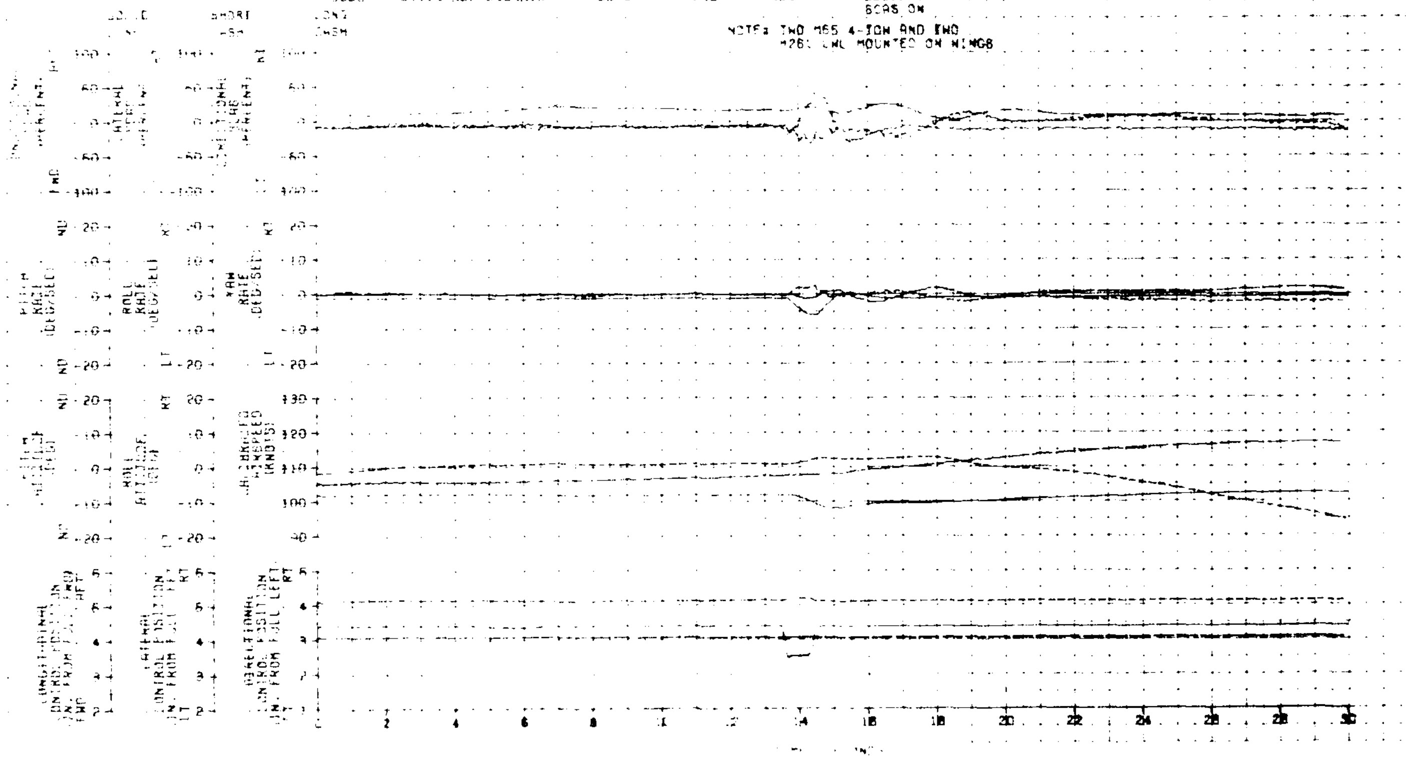


FIGURE 9
LATERAL PULSE
RH-1S USR S/N 76-22573

GROSS WEIGHT (LB)	C.G. LOCATION LONG. (FS)	C.G. LOCATION LAT. (BL)	DENSITY ALTITUDE (FT)	OAT (C)	ROTOR SPEED (RPM)	FLIGHT CONDITION
8780	184.7(FWD)	0.0(MID)	5880	8.5	324	LEVEL SCAS ON

NOTE: TWO M65 4-TOW AND TWO M261 LHL MOUNTED ON WINGS

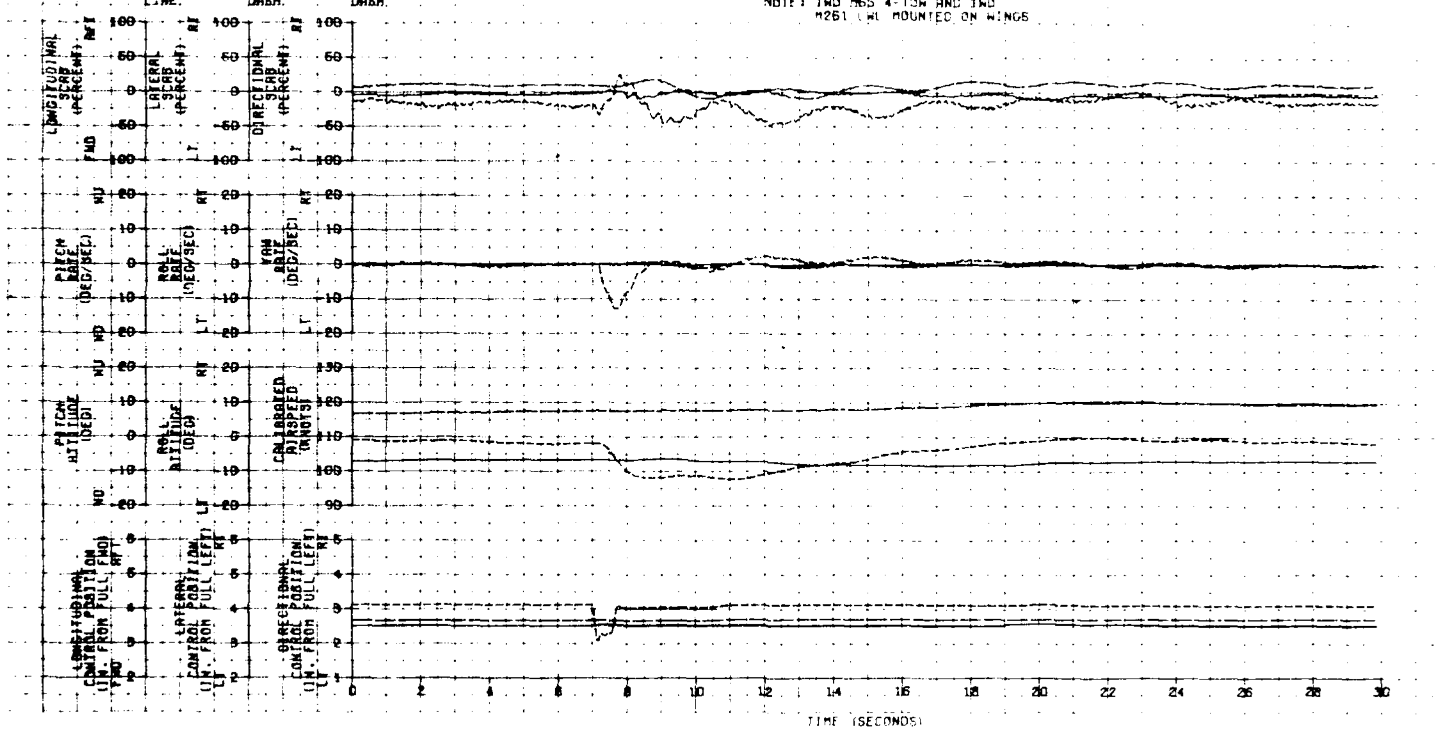


FIGURE 12.
LATERAL DOUBLET
AH-1F USA S/N 76-22573

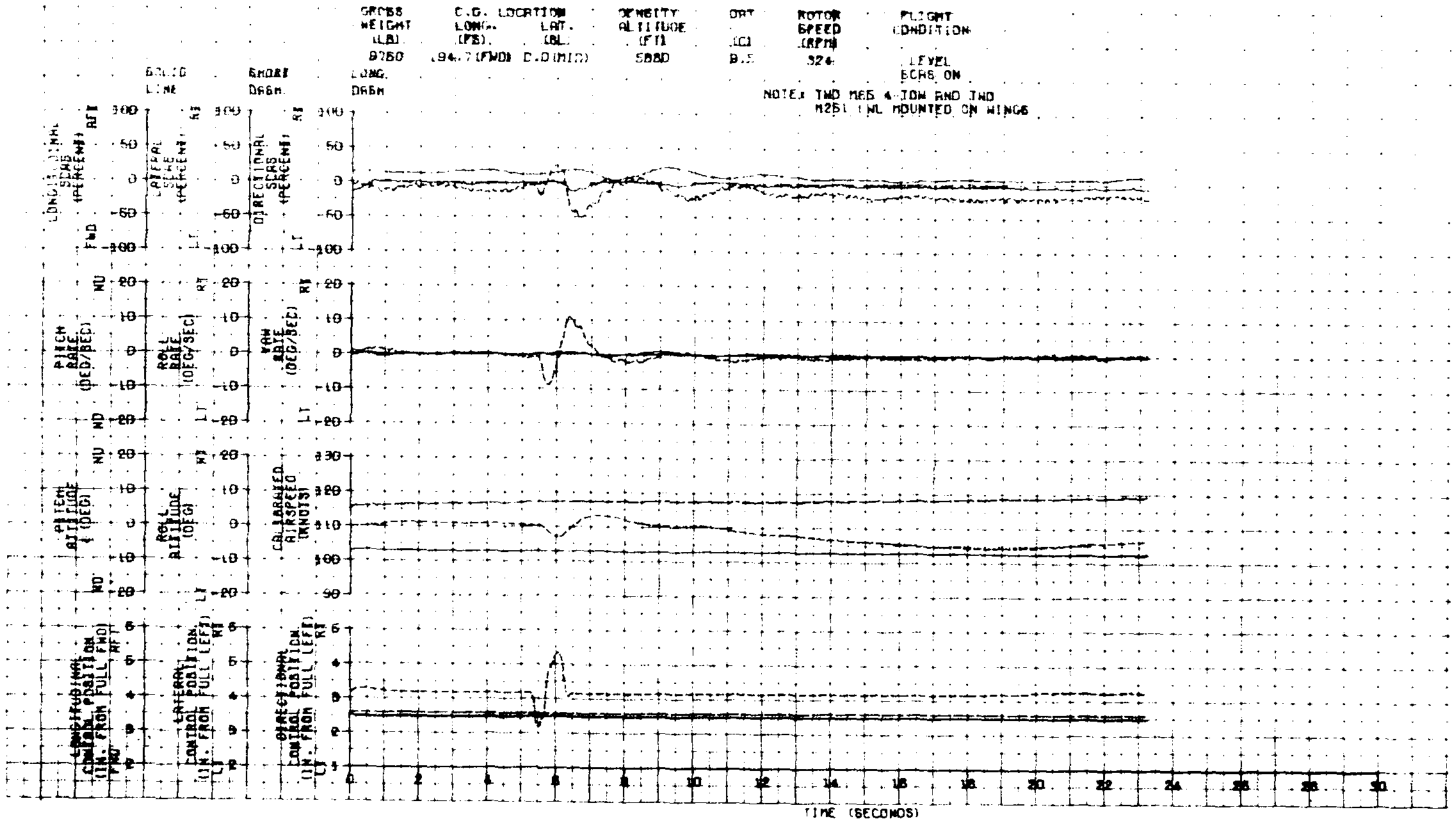


FIGURE 11
DIRECTIONAL DOUBLET
AH-1S USA S/N 76-22573

GROSS WEIGHT (LB)	C.G. LOCATION LONG. (FS)	C.G. LOCATION LAT. (BL)	DENSITY ALTITUDE (FT)	OAT (C)	ROTOR SPEED (RPM)	FLIGHT CONDITION
9780	194.7(FWD)	0.0(MID)	5880	8.5	324	LEVEL SCAS ON

NOTE: TWO M65 4-TOW AND TWO M261 LWL MOUNTED ON WINGS

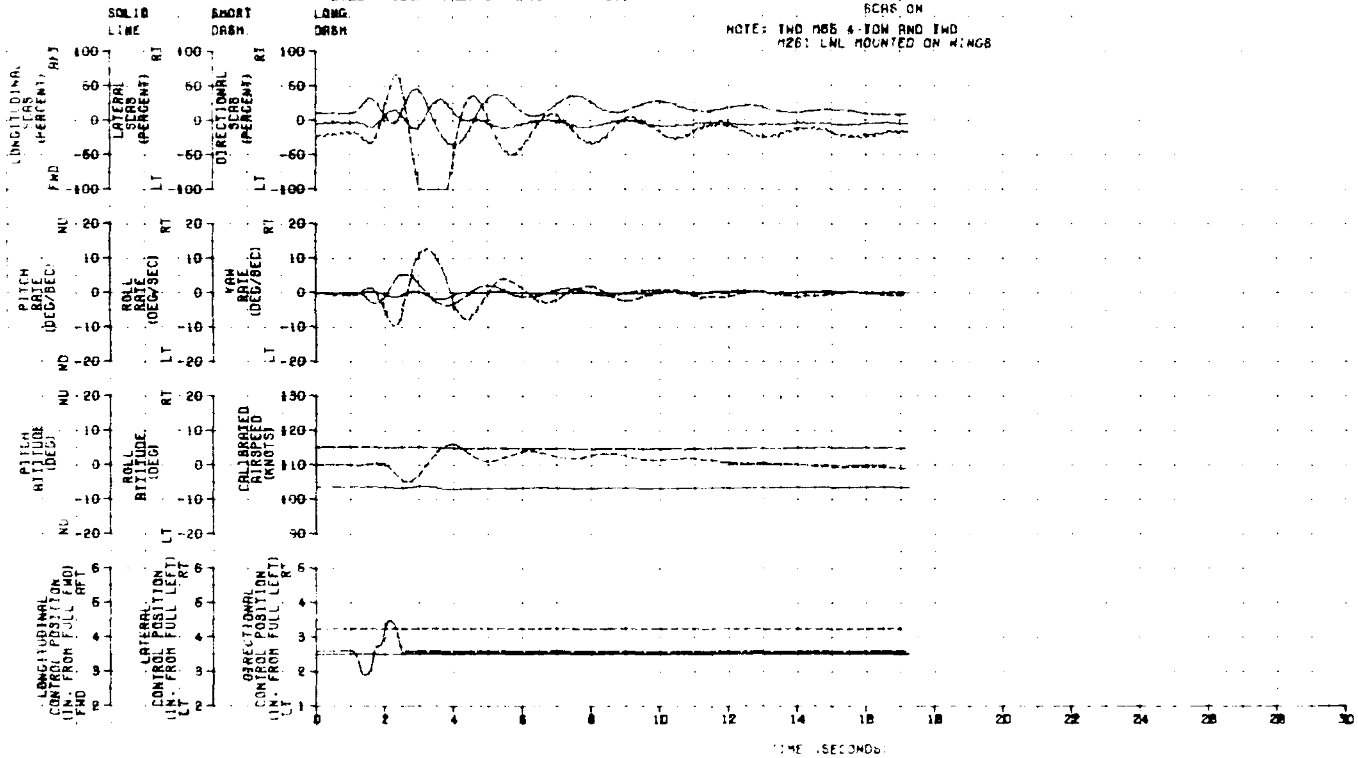


FIGURE 12
SPIRAL STABILITY
AH-1S USA S/N 76-22573

GROSS WEIGHT (LB)	C.G. LOCATION LONG. (FS)	C.G. LOCATION LAT. (BL)	DENSITY ALTITUDE (FT)	OAT (C)	ROTOR SPEED (RPM)	FLIGHT CONDITION
9220	194.3(FWD)	0.0(MID)	5800	18.5	324	LEVEL SCAS ON

NOTE: TWO M65 6-TOW AND TWO M281 LWL MOUNTED ON WINGS

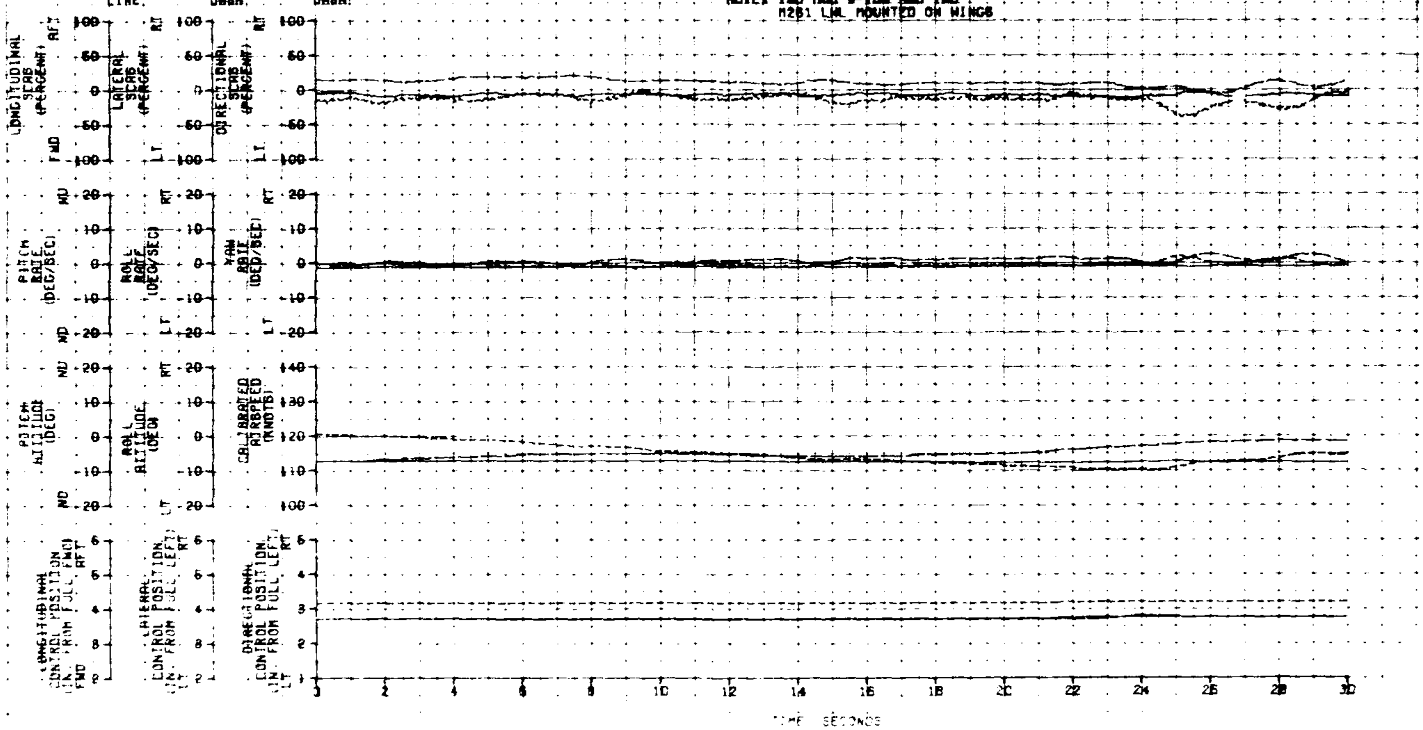
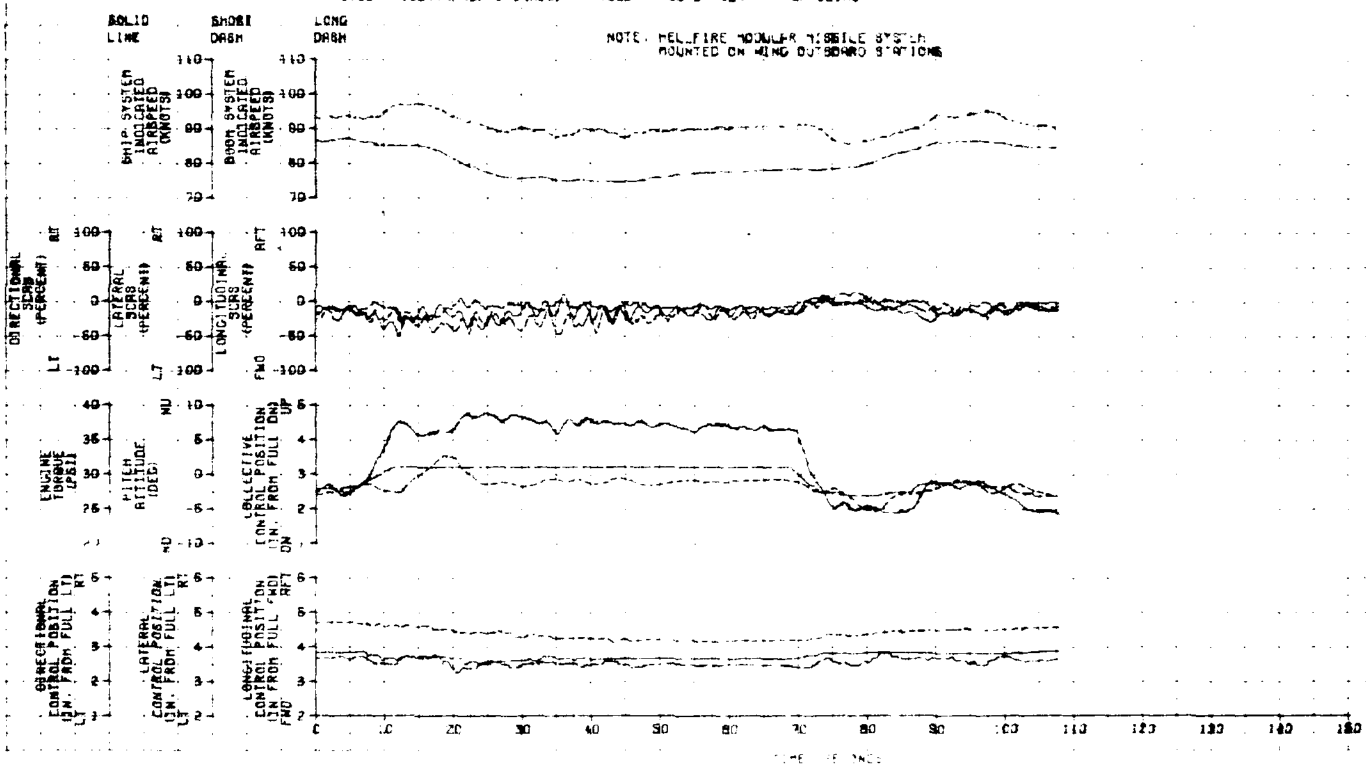


FIGURE 13
BOOM SYSTEM AND SHIP'S SYSTEM AIRSPEED COMPARISON
AH-1S USA S/N 76-22573

GROSS WEIGHT (LB)	CG LOCATION LONG (FS)	CG LOCATION LAT (BL)	DENSITY ALTITUDE (FEET)	OAT (°C)	ROTOR SPEED (RPM)	FLIGHT CONDITION
8700	198.7(FWD)	0.0(MID)	7920	28.5	324	MCP CLIMB

NOTE: HELLFIRE MODULAR MISSILE SYSTEM MOUNTED ON WING OUTBOARD STATIONS



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